VERIFICATION OF TRANSLATION

Re: Japanese Patent Application No. 2004-100032

I, Tsuyoshi Kumano of 1-50, Hagiharadai-nishi, Kawanishi-shi, Hyogo-ken, Japan, hereby declare that I am the translator of the documents attached and certify that the following is a true translation to the best of my knowledge and belief.

Signature of translator ....

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[Claims]

1. A dynamic pressure bearing device comprising:

a fixed-side member;

a rotational-side member;

a thrust bearing surface formed on any one of the fixed-side member and the rotational-side member, the thrust bearing surface including a dynamic pressure generating groove area having a plurality of dynamic pressure generating grooves being arranged thereon;

a thrust receiving surface provided on the other one of the fixed-side member and the rotational-side member so as to be opposed to the thrust bearing surface in an axial direction; and

a thrust bearing gap formed between the thrust bearing surface and the thrust receiving surface, the thrust bearing gap being for generating a pressure by a dynamic pressure effect of a fluid during rotation of the rotational-side member so as to support a rotary member in an axial direction in a non-contact manner by the pressure, wherein

a reduced portion having an axial width decreasing in a radially outward direction is provided in the thrust bearing gap.

2. The dynamic pressure bearing device according to claim 1, wherein at least one of the thrust bearing surface and the thrust receiving surface of the reduced portion is formed as an inclined plane.

3. The dynamic pressure bearing device according to claim 2, wherein a ratio is set such that $h/r \leqq 0.01$ where a length of the inclined plane in a radial direction is r and a height of the inclined plane is h.

4. A motor having: the dynamic pressure bearing device according to any one of claims 1 to 3, a rotor attached to the rotational-side member; and a stator attached to the fixed-side

member.

[Name of document] Specification

[Title of invention] DYNAMIC PRESSURE BEARING DEVICE

[Detailed description of the invention]

[Technical field of the invention]

[0001]

The present invention relates to a dynamic pressure bearing device. This bearing device is suitable for: a spindle motor for information equipment, for example, a magnetic disk device such as an HDD or an FDD, an optical disk device for a CD-ROM, a DVD-ROM or the like, and a magneto-optical disk device for an MD, an MO or the like; a polygon scanner motor for a laser beam printer (LBP); and a small motor for electric equipment, for example, an axial fan and the like.

[Background Art]

[0002]

The above-mentioned various motors are required to operate not only with high rotational accuracy but also at higher speed, lower cost, and lower noise. One of the components determining the required performance is a bearing for supporting a spindle of the motor. As this type of bearing, a dynamic pressure bearing device having characteristics excellent in the above-mentioned required performance has been considered for use or has been put into practical use in recent years.

[0003]

As an example of the dynamic pressure bearing device, Japanese Patent Laid-Open Publication No. 2002-61641 discloses a dynamic pressure bearing device having the following structure. The dynamic pressure bearing device includes: a cylindrical housing with a closed end; a bearing member fixed to an inner periphery of the housing; a shaft member inserted onto an inner peripheral face of the bearing member; and a radial bearing portion and a thrust bearing portion, which rotatably support the shaft member in a non-contact manner by a dynamic pressure effect generated during the relative rotation of the shaft member and a bearing sleeve.

[0004]

Of the radial bearing portion and the thrust bearing portion, the thrust bearing portion generates a pressure by a dynamic pressure effect of oil in each of thrust bearing gaps between both end faces of a flange of the shaft member and a bottom face of the housing and an end face of the bearing sleeve, which are opposed thereto, so as to support the shaft member in an axial direction in a non-contact manner.

[Prior art document] JP2002-61641A1

[Disclosure of invention]

[Problems to be solved by the invention]

[0005]

In this type of dynamic pressure bearing device, a member on the rotational side and a member on the fixed side inevitably slide with each other at high speed when the dynamic pressure bearing device starts and stops operating. Therefore, in the dynamic pressure bearing device used for information equipment in which the operation of a motor is frequently started and stopped, for example, consumer equipment including an HDD-DVD recorder and a storage device for a cell-phone, the wear of a sliding face caused by repeated start and stop of the operation emerges as a problem under some conditions for use and the like. Thus, wear resistance is desired to be further improved.

[0006]

In view of the above problems, the present invention has an object of providing a dynamic pressure bearing device capable of preventing wear of a thrust bearing portion.

[Means for solving the problems]

[0007]

In order to achieve the above object, a dynamic pressure bearing device according to the present invention comprises: a fixed-side member; a rotational-side member; a thrust bearing surface formed on any one of the fixed-side member and the rotational-side member, the thrust bearing surface including a dynamic pressure generating groove area having a plurality of dynamic pressure generating grooves being arranged thereon;

a thrust receiving surface provided on the other one of the fixed-side member and the rotational-side member so as to be opposed to the thrust bearing surface in an axial direction; and a thrust bearing gap formed between the thrust bearing surface and the thrust receiving surface, the thrust bearing gap being for generating a pressure by a dynamic pressure effect of a fluid during rotation of the rotational-side member so as to support a rotary member in an axial direction in a non-contact manner by the pressure, wherein a reduced portion having an axial width decreasing in a radially outward direction is provided in the thrust bearing gap.

[0008]

With this structure, the radially outermost portion of the reduced portion having a high peripheral speed has the minimum width thereby pumping function of the dynamic pressure generating grooves becomes high. As a result, contact time between the thrust bearing surface and the thrust receiving surface at the start or the stop of operation of a motor can be reduced.

[0009]

The thrust bearing gap can be obtained by forming at least one of the thrust bearing surface and the thrust receiving surface of the reduced portion as an inclined plane. In this case, it is desirable to set a ratio: $h/r \leqq 0.01$ where a length of the inclined plane in a radial direction is r and a height of the inclined plane is h so as to prevent the dynamic pressure effect from getting worse or the like.

[0010]

A motor including: the above-described dynamic pressure bearing device; a rotor attached to the rotational-side member; and a stator attached to the fixed-side member has high durability as well as high rotational accuracy. Therefore, the motor is suitable as a motor for information equipment.

[Effects of the invention]

[0011]

According to the invention, since wear of the thrust

bearing portion can be prevented according to the present invention, the durability of the dynamic pressure bearing device can be improved.

[Best mode for carrying out the invention]

[0012]

Hereinafter, embodiments of the present invention will be described.

[0013]

Fig. 1 shows a spindle motor used for a disk drive device such as an HDD as an example of a spindle motor for information equipment incorporating a dynamic pressure bearing device 1. The motor includes: the dynamic pressure bearing device 1; a rotational member 3 (a disk hub) attached to a shaft member 2 of the dynamic pressure bearing device 1; a stator 4 of the motor 4 and a rotor 5 of the motor provided so as to be opposed to each other, for example, through a radial gap; and a bracket 6. The stator 4 is attached to an outer periphery of the bracket 6. The rotor 5 is attached to an inner periphery of the disk hub 3. The disk hub 3 retains one or a plurality of disks D such as a magnetic disk on its outer periphery. A housing 7 of the dynamic pressure bearing device 1 is attached to an inner periphery of the bracket 6. When the stator 4 is energized, the rotor 5 is rotated by an excitation force generated between the stator 4 and the rotor 5. With the rotation of the rotator 5, the disk hub 3 rotates, which in turn rotates the shaft member 2.

[0014]

Fig. 2 shows an example of the dynamic pressure bearing device 1 described above. The dynamic pressure bearing device 1 includes: radial bearing portions R1 and R2 for supporting the shaft member 2 in a radial direction; and thrust bearing portions T1 and T2 for supporting the shaft member 2 in an axial direction. Each of the radial bearing portions R1 and R2 and the thrust bearing portions T1 and T2 is constituted by a dynamic pressure bearing. The dynamic pressure bearing forms a bearing surface including dynamic pressure generating grooves on any

one of a rotational-side member and a fixed-side member while forming a smooth receiving surface on the other member so as to be opposed to the bearing surface. During rotation of the rotational-side member, a pressure is generated by a dynamic pressure effect of a fluid in a bearing gap between the bearing surface and the receiving surface to rotatably support the rotational-side member in a non-contact manner.

[0015]

Hereinafter, a specific structure of the dynamic pressure bearing device 1 will be described.

[0016]

As shown in Fig. 2, the dynamic pressure bearing device 1 according to this embodiment includes as principle bearing components: the cylindrical housing 7 having a closed end and an opening 7a on the other end; a cylindrical bearing sleeve 8 fixed onto an inner peripheral face of the housing 7; the shaft member 2; and a sealing member 10 fixed into the opening 7a of the housing 7. For convenience of description, the opening side of the housing 7 is referred to as an upper side while the opposite side in the axial direction is referred to as a lower side in the following description.

[0017]

The housing 7 is formed in a cylindrical shape with a closed end, including a cylindrical side portion 7b and a bottom portion 7c. In this embodiment, the bottom portion 7c is formed by a disc-like thin thrust plate as a member independent of the side portion 7b. The thrust plate 7c is bonded to and/or pressed into a lower opening of the side portion 7b so as to be attached thereto, thereby forming the housing 7 having a closed end. The bottom portion 7c of the housing 7 may be integrally formed with the side portion 7b.

[0018]

The shaft member 2 is, for example, entirely formed of a metal material such as stainless steel (SUS420J2). The shaft member 2 includes: a shaft portion 2a; and a flange portion 2b provided on a lower end of the shaft portion 2a so as to be

extended in a radially outward direction. The shaft portion 2a and the flange portion 2b are provided integrally or independently. A lower end face 2b1 of the flange portion 2b is opposed to an upper end face 7c1 of the thrust plate 7c, whereas an upper end face 2b2 of the flange portion 2b is opposed to a lower end face 8c of the bearing sleeve 8. The lower end face 2b1 and the upper end face 2b2 of the flange portion 2b function as thrust receiving surfaces 11b and 13b, respectively, as described below.

[0019]

In this embodiment, a part of the upper end face 7c1 of the thrust plate 7c, which is opposed to the lower end face 2b1 of the flange portion 2b, serves as the thrust bearing surface 11a of the lower thrust bearing portion T1. On a part of the thrust bearing surface 11a, for example, in the vicinity of the radial center of the thrust bearing surface 11a, a dynamic pressure generating groove area P is annularly formed as shown in Fig. 3. The dynamic pressure generating groove area P is formed by spirally arranging a plurality of dynamic pressure generating grooves P1 and a plurality of ridges P2, each forming a like-hill between the dynamic pressure generating grooves P1. Although a method of processing the dynamic pressure generating groove area P is arbitrary, press working is desirable because it allows the formation of the dynamic pressure generating groove area P at low cost with high accuracy. In this case, in order to improve the processability in press working, it is desirable to form the thrust plate 7c of a soft metal material with a small yield stress, for example, a copper alloy (such as brass, a zinc bronze, lead bronze or phosphor bronze) or aluminum (A2 to 7). A pattern of the dynamic pressure generating grooves in the dynamic pressure generating groove area P is arbitrary and can be arranged in a herringbone pattern.

[0020]

The bearing sleeve 8 is formed of an oil-impregnated sintered metal in a cylindrical shape. The oil-impregnated sintered metal is obtained by impregnating, for example, a

porous material, in particular, a sintered metal on the basis of copper into a lubricating oil (or a lubricating grease). A radial bearing surface of the first radial bearing portion R1 and a radial bearing surface of the second radial bearing portion R2 are provided on an inner peripheral face 8a of the bearing sleeve 8 so as to be axially separated from each other. Dynamic pressure generating grooves in, for example, a herringbone pattern are formed in each of the two areas. A spiral pattern, an axial groove pattern or the like may be used as a pattern of the dynamic pressure generating grooves. The radial bearing surfaces including the dynamic pressure generating grooves may also be formed on an outer peripheral face of the shaft portion 2a of the shaft member 2. Furthermore, the bearing sleeve 8 may be formed of a material other than the porous material, for example, a soft metal such as brass or a copper alloy.

[0021]

In this embodiment, the lower end face 8c of the bearing sleeve 8 serves as a thrust bearing surface 13a of the upper thrust bearing portion T2. On the thrust bearing surface 13a, an annular dynamic pressure generating groove area (not shown) where a plurality of dynamic pressure generating grooves are spirally arranged is formed. A pattern of the dynamic pressure generating grooves is arbitrary and can be arranged in a herringbone pattern.

[0022]

As shown in Fig. 2, the sealing member 10 is annular and is fixed into an inner peripheral face of the opening 7a of the housing 7 by means such as pressing or bonding. In this embodiment, an inner peripheral face 10a of the sealing member 10 is formed in a cylindrical shape, and a lower end face of the sealing member 10 abuts against the upper end face 8b of the bearing sleeve 8.

[0023]

The shaft portion 2a of the shaft member 2 is inserted onto the inner peripheral face 8a of the bearing sleeve 8. The

flange portion 2b is housed in a space between the lower end face 8c of the bearing sleeve 8 and the upper end face 7c1 of the thrust plate 7c. A tapered surface 2a of the shaft portion 2a is opposed to the inner peripheral face 10a of the sealing member 10 with a predetermined gap therebetween. As a result, a tapered sealed space S that gradually expands in the outer direction of the housing 7 (upwardly in the drawing) is formed between the tapered surface 2a and the inner peripheral face 10a. During the rotation of the shaft member 2, the tapered surface 2a1 of the shaft portion 2a also serves as a so-called centrifugal seal. An internal space in the housing 7 (including pores in the bearing member 8) sealed by the sealing member 10 is filled with a lubricating oil. An oil level of the lubricating oil is present in the sealed space S. The sealed space S is formed not only in a tapered shape as described above but also in a cylindrical shape having the same diameter in the axial direction.

[0024]

During the rotation of the motor, the shaft member 2 serves as a rotational-side member, whereas the housing 7, the bearing sleeve 8 and the sealing member 10 serve as fixed-side members in the above-described embodiment. When the shaft member 2 is rotated, a pressure is generated by a dynamic pressure effect of the lubricating oil in a radial bearing gap between the radial bearing surface on the inner peripheral face of the bearing sleeve 8 and the outer peripheral face of the shaft portion 2a (the radial receiving surface) being opposed thereto in the radial bearing portions R1 and R2. As a result, the shaft portion 2a of the shaft member 2 is supported so as to be rotatable in the radial direction in a non-contact manner. Moreover, in the lower thrust bearing portion T1, a pressure is generated by a dynamic pressure effect of the lubricating oil in the thrust bearing gap between the thrust bearing surface 11a formed on the thrust plate 7c and the thrust receiving surface 11b (the lower end face 2b1 of the flange portion 2b) being opposed thereto. At the same time, in the upper thrust

bearing portion T2, a pressure is generated by a dynamic pressure effect of the lubricating oil in a thrust bearing gap between the thrust bearing surface 13a formed on the end face 8c of the bearing sleeve 8 and the thrust receiving surface 13b (the upper end face 2b2 of the flange portion 2b) being opposed thereto. Therefore, the flange portion 2b of the shaft member 2 is supported so as to be rotatable in the axial direction in a non-contact manner.

[0025]

Although the thrust bearing surface 11a including the dynamic pressure generating groove area P and the thrust bearing surface 13a including the dynamic pressure generating groove area not shown are formed on the upper end face 7c1 of the thrust plate 7c and the lower end face 8c of the bearing sleeve 8, respectively, in the above-described embodiment, the thrust bearing surfaces 11a and 13a may also be formed on any one of or both of the end faces 2b1 and 2b2 of the flange portion 2b. In this case, the smooth thrust receiving surface 11b or 13b without a dynamic pressure generating groove is formed on the upper end face 7c1 of the thrust plate 7c or the lower end face 8c of the bearing sleeve 8.

[0026]

In the present invention, as shown in Fig. 4, a reduced portion 15 formed by gradually reducing an axial width W in the radially outward direction is formed in the thrust bearing gap C of the lower thrust bearing portion T1 (a width of the thrust bearing gap C is illustrated in an exaggerated manner in Fig. 4). Fig. 4 shows an embodiment where a uniform portion 14 having a constant width is provided as a radially inner part of the thrust bearing gap C and the reduced portion 15 is provided on the radially outer side thereof. The reduced portion 15 can be formed by, as shown in the drawing for example, forming the thrust receiving face 11b as a flat plane in a direction perpendicularly crossing the axial direction and providing an inclined plane 17 coming closer to the thrust receiving surface 11b in the radially outward direction on the thrust bearing

surface 11a. It is preferable that the dynamic pressure generating groove area P of the thrust bearing surface 11a is provided on the inclined plane 17.

[0027]

By forming the reduced portion 15 in the thrust bearing gap C as described above, a radially outermost portion of the reduced portion 15 corresponds to the minimum width portion Wmin of the thrust bearing gap C. Since a peripheral speed at the radially outermost portion of the reduced portion is high during the rotation of the shaft member 2, pumping power of the dynamic pressure generating grooves becomes high. Therefore, an enough dynamic pressure action can be obtained even at low rotational speed thereby a contact start rotational speed of the bearing device 1 can be kept low. As a result, the wear of the thrust bearing portion T1 due to sliding contact between the thrust bearing surface and the thrust receiving surface can be prevented, thereby providing the dynamic pressure bearing device 1 suitable for use in the case where the motor operation is frequently started and stopped.

[0028]

Herein, the contact start rotational speed is such a rotational speed that the thrust bearing surface 11a and the thrust receiving surface 11b come into contact with each other at a speed lower than it, whereas the surfaces 11a and 11b do not come into contact with each other at a speed higher than it. Since contact time between the thrust bearing surface 11a and the thrust receiving surface 11b immediately after the start or immediately before the stop of the operation of the motor is reduced if the contact start rotation speed is lowered, the wear of the thrust bearing portion T1 can be prevented.

[0029]

Such effects can be obtained as long as the thrust bearing gap C has the reduced portion 15. Besides the inclined plane 17 provided on the thrust bearing surface 11a as shown in the drawing, the thrust bearing surface 11a may be formed as a flat plane, whereas an inclined plane may be provided on the thrust

receiving surface 11b. Alternatively, inclined planes may be formed both on the thrust bearing face 11a and the thrust receiving face 11b. Furthermore, the inclined plane 17 may be formed not only as a tapered plane having a straight cross section as shown in Fig. 4 but also in a curved surface having a circular cross-section having a radius R (including a composite curved surface obtained by combining circles having two or more radii) as shown in Fig. 6.

[0030]

Moreover, although only the case where the reduced portion 15 is provided in the thrust bearing gap C of the lower thrust bearing portion T1 is illustrated in Fig. 4, the same effects can be obtained if the same reduced portion is formed in the thrust bearing gap of the upper thrust bearing portion T2.

[0031]

In order to confirm the above-described effects, a theoretical calculation of the contact start rotational speed is performed for the dynamic pressure bearing device according to the present invention and a comparative dynamic pressure bearing device. Herein, the dynamic pressure bearing device according to the present invention includes the thrust bearing gap having the reduced portion 15 as shown in Fig. 4, whereas the comparative bearing device includes the thrust bearing gap having an expanded portion 15′ having an increasing axial width in the radially outward direction as shown in Fig. 5 (in Fig. 5, the members corresponding to those shown in Fig. 4 are denoted by the reference numerals with the apostrophe(′)).

[0032]

The theoretical calculation is performed with reference to the following document: Jiasheng Zhu and Kyosuke Ono, 1999, "A Comparison Study on the Performance of Four Types of oil Lubricated Hydrodynamic Thrust Bearings for Hard Disk Spindles", Transactions of the ASME, Vol.121, JANUARY 1999, pp. 114-120.

[0033]

The calculation conditions (a DF method and Sommerfeld

boundary conditions) used in the theoretical calculation are as follows.

[0034]

Weight of rotary part W	6.5 g
Outer diameter of thrust bearing portion Do	6.5 mm
Inner diameter of thrust bearing portion Di	2.5 mm
Groove depth ho	7 μm
Number of grooves k	16
Groove angle α	30 degrees
Hill/groove ratio γ	1
Lubricating oil viscosity η	5.97 mPa·S

The minimum width Wmin of the thrust bearing gap is set to 0.05 μm.

[0035]

The result of the theoretical calculation based on the above-described conditions is shown in Fig. 7. The "flatness" on the abscissa axis in Fig. 7 indicates a height h of the inclined plane 17 shown in Figs. 4 and 5.

[0036]

As can be seen from the drawing, the dynamic pressure bearing device A according to the present invention has a lower contact start rotational speed than that of the comparative product B. Therefore, it is found that the dynamic pressure bearing device A according to the present invention is effective for reducing the contact time between the thrust bearing surface 11a and the thrust receiving surface 11b immediately after the start or immediately before the stop of the motor operation. Moreover, from the result shown in Fig. 7, if the flatness of the thrust bearing surface 11a (the height h of the inclined plane 17) is too high, the contact start rotational speed is correspondingly increased to disadvantageously reduce the dynamic pressure effects. Therefore, it is considered the flatness h has an upper limit. As the result of examination by the inventors of the present invention from this point of view, it is found that the contact start rotational speed is remarkably increased if a ratio of the height h of the inclined

plane 17 to its radius r (h/r) exceeds 0.01. Therefore, it is desirable that a value of h/r is 0.01 or less, more desirably, 0.004 or less.

[0037]

The comparative product shown in Figure 5 has the advantage that pressure of the contact area between the thrust bearing surface 11a' and the thrust receiving surface 11b' becomes small compared with product of the present invention though the contact start rotational speed of the comparative product is inferior to the present invention.

[0038]

The application of the present invention is not limited to the dynamic pressure bearing device 1 having the thrust bearing portion T1 between the lower end face 2b1 of the flange portion 2b and the bottom portion 7c of the housing 7; the present invention can be widely applied to dynamic pressure bearing devices including a thrust bearing portion constituted by a dynamic pressure bearing in general. For example, the present invention is similarly applicable to the following dynamic pressure bearing device (not shown). One of the thrust bearing surface 11a and the thrust receiving surface 11b of the thrust bearing portion is formed on the end of the housing 7 on the opening side, while the other is formed on an end face of a rotary member (for example, the disk hub 3) being opposed thereto.

[0039]

The case where the dynamic pressure bearing including the dynamic pressure generating grooves is used as each of the radial bearing portions R1 and R2 has been described above. However, any bearing can be used as the radial bearing portions R1 and R2 as long as it supports the shaft member 2 in the radial direction in a non-contact manner by an oil film of the lubricating oil, formed in the radial bearing gap. For example, in addition to a bearing including an area serving as the radial bearing surface being composed of a plurality of circles (a circular bearing) and a step bearing, a bearing including an area having a perfect circular cross section without any dynamic

pressure generating grooves as the radial bearing surface (a cylindrical bearing) can also be used.

[Brief Description of Drawings]

[0040]

[Fig. 1] Fig. 1 is a cross-sectional view of a spindle motor using a dynamic pressure bearing device according to the present invention;

[Fig. 2] Fig. 2 is a cross-sectional view of the dynamic pressure bearing device;

[Fig. 3] Fig. 3 is a plan view of a thrust bearing surface (an upper end face of a thrust plate);

[Fig. 4] Fig. 4 is an enlarged sectional view schematically showing a lower thrust bearing portion;

[Fig. 5] Fig. 5 is an enlarged sectional view schematically showing a comparative thrust bearing portion;

[Fig. 6] Fig. 6 is a cross-sectional view showing another example of an inclined plane;

[Fig. 7] Fig. 7 is a diagram showing the result of a theoretical calculation of a contact start rotational speed.

[Description of Reference Characters]

[0041]

1 dynamic pressure bearing device
2 shaft member
2a shaft portion
2b flange portion
2b1 lower end face
2b2 upper end face
3 rotational member
4 stator of the motor
5 rotor of the motor
7 housing
7c thrust plate
7c1 upper end face
8 bearing sleeve
8a inner peripheral face
8c end face

10	seal member
10a	inner peripheral face
11a	thrust bearing surface
11b	thrust receiving surface
13a	thrust bearing surface
13b	thrust receiving surface
15	reduced portion
17	inclined plane
P	dynamic pressure generating groove area
R1	first radial bearing portion
R2	second radial bearing portion
T1	first thrust bearing portion
T2	second thrust bearing portion

[Name of document] Written abstract

[Object] The present invention has an object of improving wear resistance of a thrust bearing portion.

[Constitution] A pressure is generated by a dynamic pressure effect of a lubricating oil in a thrust bearing gap C between a thrust bearing surface 11a including dynamic pressure generating grooves and a smooth thrust receiving surface 11b so as to rotatably support a shaft member 2 in an axial direction. The thrust receiving surface 11b is formed as a flat surface, whereas an inclined plane 17 is provided on the thrust bearing surface 11a so as to provide a reduced portion 15 having a decreasing axial width in a radially outward direction in the thrust bearing gap C.

[Representative Drawing] Fig. 4